Imagination
TECHNOLOGIES

Augmented Reality on Mobile Platforms

POWERVR Developer Technology

August 2010

Imagination Overview

- **Leading Semiconductor IP Supplier**
  - POWERVR™ graphics, video, display processing
  - ENSIGMA™ receivers and communications processors
  - META™ processors – SoC centric real-time, DSP, Linux
  - Licensees: Leading Semis and OEMs
  - #4 Silicon Design IP provider *

- **Innovative Consumer Product Manufacturer**
  - PURE digital radio, internet connected audio

- **Established technology powerhouse**
  - Founded:1985
  - Listed:1994-London Stock Exchange:IMG
  - Employees: more than 620 worldwide

** Source: Gartner IP Suppliers Report, March 2009*

UK Headquarters

R&D

Sales

POWERVR Graphics

- **Unique Tile Based Deferred Rendering architecture (TBDR)**
  - Enhances performance
  - Reduces power consumption
- **MBX Series**
  - Fixed-function graphics acceleration
  - Widely adopted in mobile devices
- **SGX Series**
  - Programmable, shader-based graphics acceleration
  - Newer technology already available in 100+ platforms


Apple iPhone 3GS


Samsung Wave


Motorola Droid/Milestone


Samsung i8910HD


Sony Ericsson Satio


Vivaz


HTC Qilin (Dopod T8388)


Nokia N900


Vodafone 360 H1 (Samsung)


Emblaze Else


Palm Pre

POWERVR Graphics

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Dell
Mini 10

Acer
Aspire One AO751H

Nokia
Booklet 3G

Sony
Vaio X-series

Sony
Vaio P-series

Asus
S121

Fujitsu
UH900

Archos 9

Sharp
Willcomm D4

Clarion
Mind

Archos 5

Apple
iTouch 32GB

Asus
R50A

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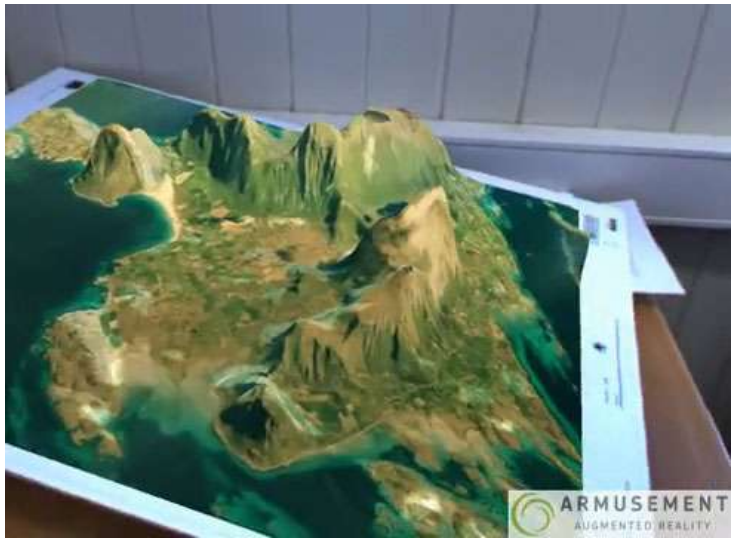
Augmented Reality

What is Augmented Reality?

- **Augmenting a view of a real scene with computer-generated images**
  - Typically reality is captured through a video stream from a camera
  - Images are rendered over the video before display to the user
  - If the video is analysed then objects in the world can be tracked and mixed with the video more realistically
    - Position, orientation and distance information is retrieved

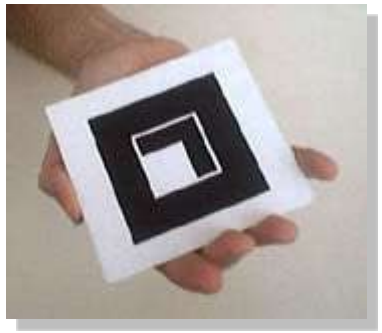
- **Applying captured images to 3D objects**
  - Use images from a camera or video source as textures
    - User interfaces
    - Refraction effects
    - Post processing

- **Example applications**
  - Games
  - Navigation
  - Medical applications (i.e. assisted surgery)



Typical AR Procedure

- **Frame is captured by the camera**
- **This may be passed to some image processing algorithms that look for features in the frame**
  - Often these are artificial markers that are easier for the analysis to find than normal features
  - Sometimes other inputs such as GPS position, accelerometer or compass information is used
- **The application then decides how this affects where and what to render in terms of additional graphics**
- **The graphics are rendered over the camera frame in a position that gives the illusion of the computer-generated content being part of the camera image**



Find AR Marker

AR on Desktop

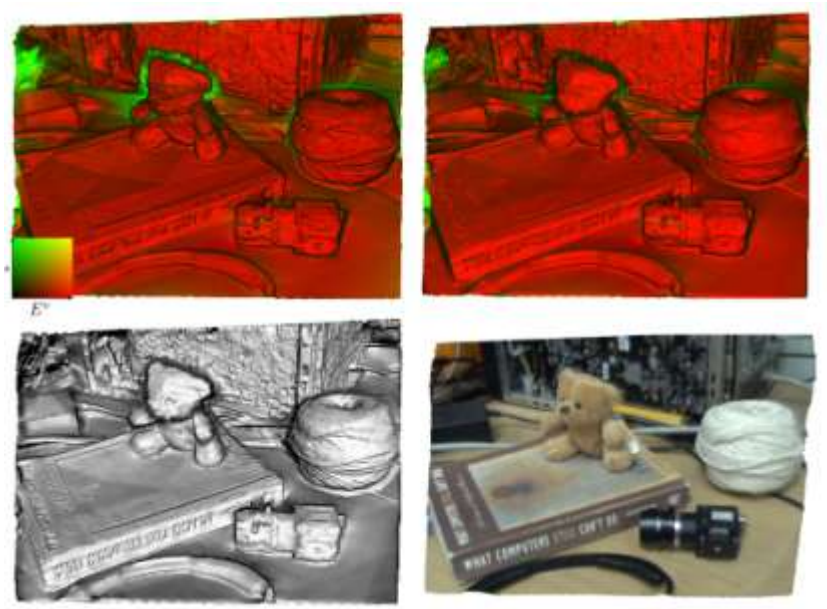
- **Benefits**
  - Fast hardware to process and analyse input images
  - Fast hardware to render graphics
  - Runs from a mains power supply (not limited by finite battery life)

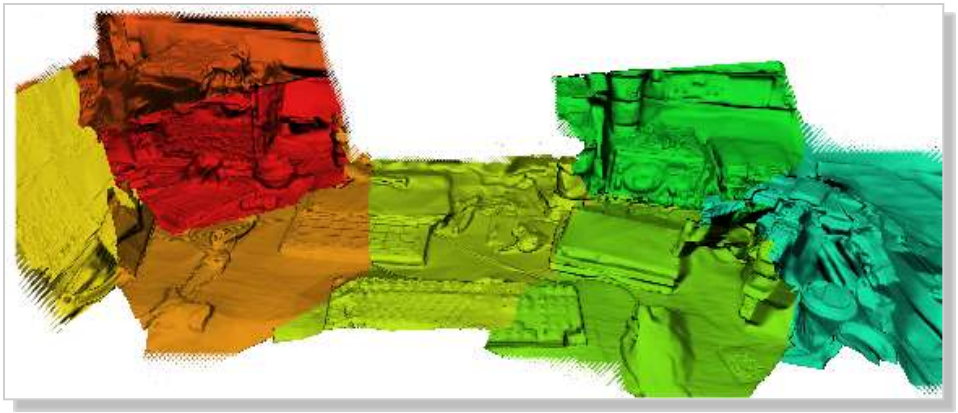
- **Drawbacks**
  - Difficult to transport
  - Clumsy to handle
  - Requires a local power supply

- **Examples**
  - Holding a marker from a magazine up to a webcam on a desktop PC allows extra content to be viewed
  - Virtual dressing rooms
    - Fixed camera
    - Sometimes no image tracking
  - Sports events
    - NFL first down marker

Research work: SLAM
AR on Desktops

- **What is SLAM?**
  - Real-time three dimensional reconstruction of scenes viewed by a single camera
  - System has a real understanding of its environment without relying on artificial aids like markers
- **Benefits**
  - Understand the position of static objects in the real world
  - Works within the restriction of a single camera input
  - No markers required
- **Drawbacks**
  - Requires high end desktop hardware to process in real-time at the moment





Material courtesy of the Imperial College of London. Available : http://www.doc.ic.ac.uk/~ajd/

AR on mobile

- **Benefits**
  - Highly transportable
  - Many modern devices, such as phones, have built in cameras
  - Large installation base of potential users
- **Drawbacks**
  - Battery constraints
  - Less processing power than desktop
    - Image analysis
    - Rendering
- **Example**

ARf virtual pet (AAEL, Georgia Tech)

AR on mobile

- **Layar**
  - Augmented reality browser for location based data
    - iPhone
    - Android

- **Kweekies**
  - Research project at int13 games

High Quality Graphics on Mobile

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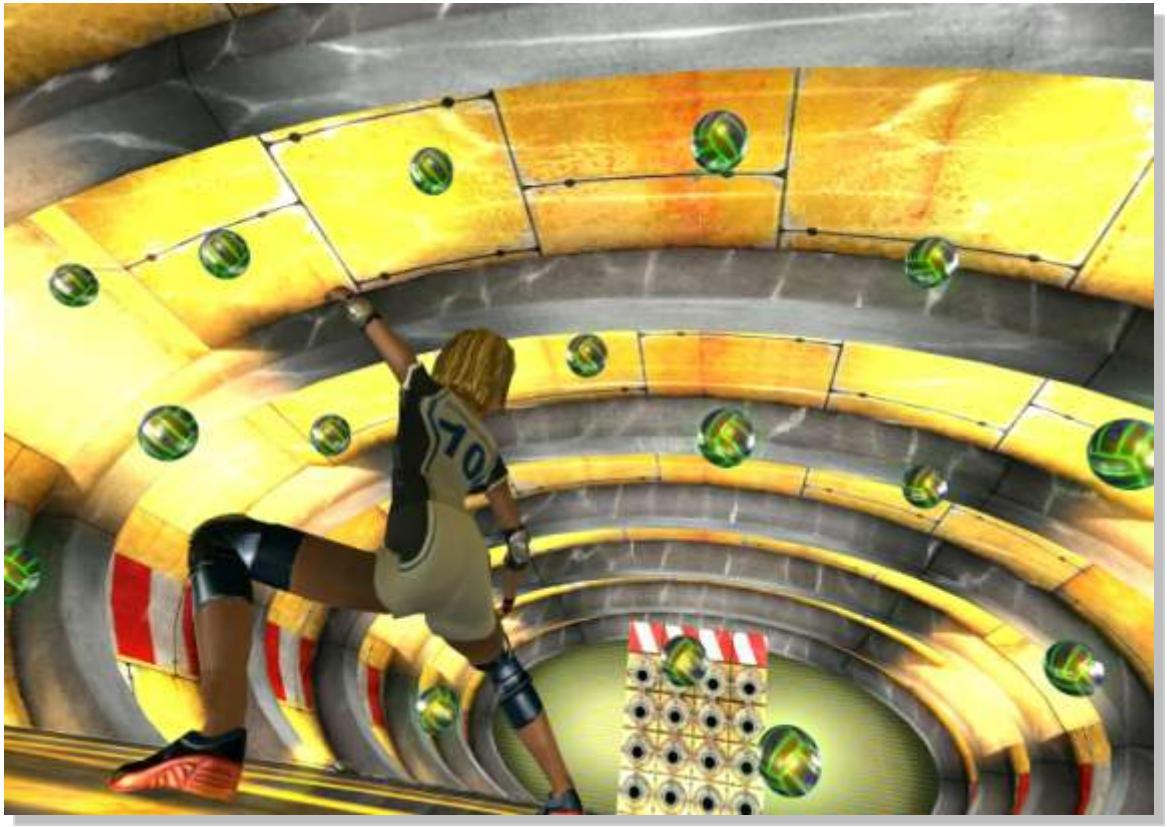
- Advanced effects and complex scenes are possible on mobile
- How can these be used in AR applications?

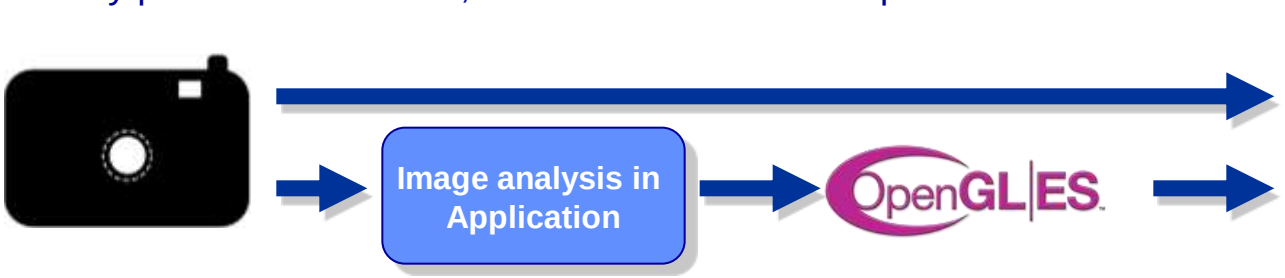


AR on Mobile
Naïve solution

- **Current implementation techniques are often inefficient**
  - Camera data is captured and copied into an application buffer
  - Image analysis is carried out here
  - The camera data is then uploaded to OpenGL ES and combined with 3D meshes
- **Benefits**
  - Easy and available on most platforms
- **Drawbacks**
  - Copying into application memory is **slow**
  - Uploading a texture each frame is **slow**
- **Bandwidth is precious on mobile systems**
  - Not much bandwidth left for graphics

AR on Mobile Overlay Solution

- **A better solution, but still not ideal**
  - Camera data is captured and sent straight to composition engine
  - Camera data is made available for application analysis
  - OpenGL ES content is rendered and overlayed by the composition hardware
- **Benefits**
  - Can be fast and is available on a number of platforms
- **Drawbacks**
  - There may still be copies in the implementation that are **slow**
  - There is no way to combine the camera data with generated graphics without uploading a texture each frame – and this is **slow**
- **Can be a fast solution, but inflexible**
  - May preserve bandwidth, restricts effects that are possible



AR on Mobile
Texture Streaming

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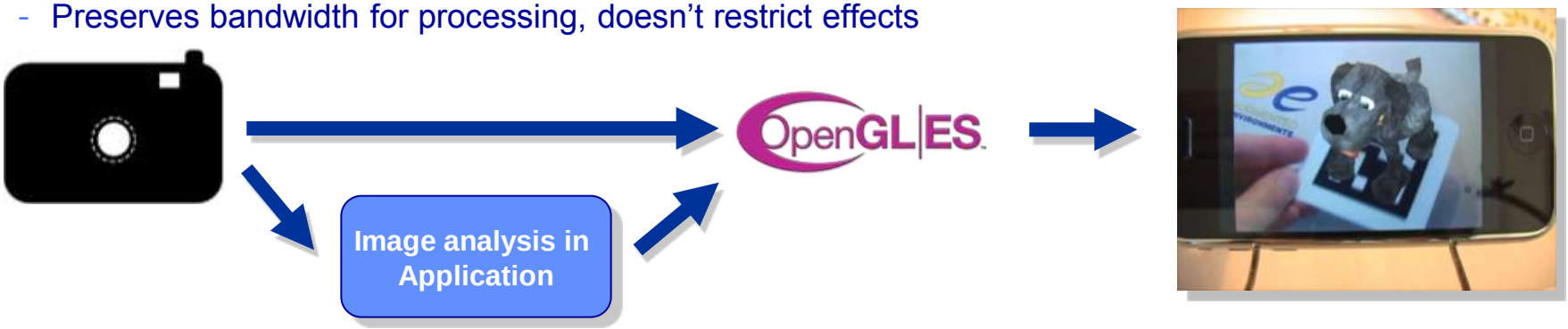
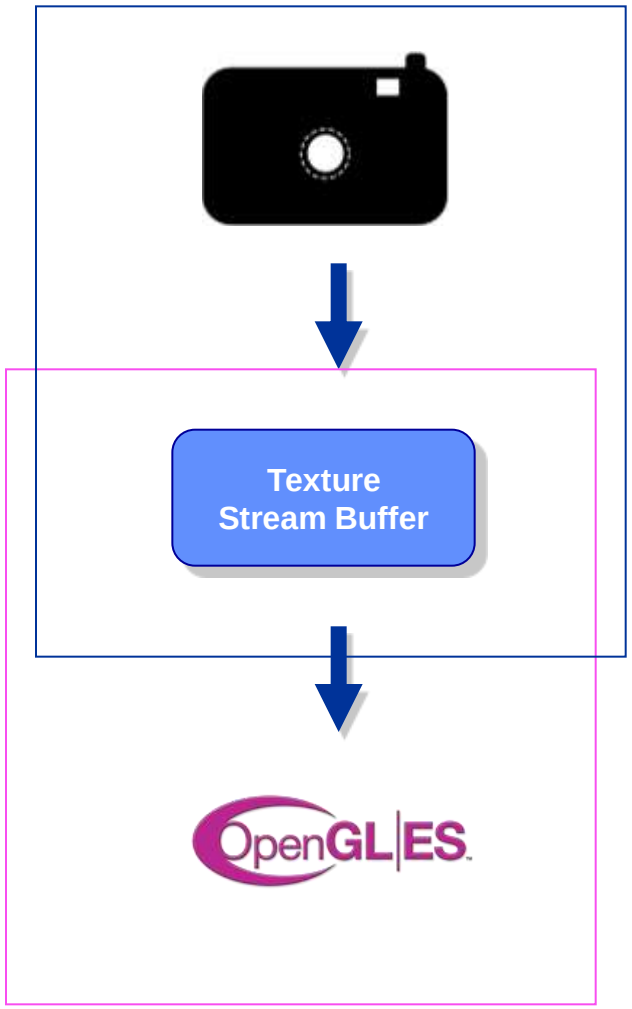
- **Probably the best solution, if available**
  - Camera data is captured and shared with OpenGL ES in a buffer – no copy
  - Camera data is made available for application analysis from this buffer – no copy
  - All rendering is done through OpenGL ES, including camera data
- **Benefits**
  - Potentially fastest and most flexible method
  - More effects available
    - 3D meshes using the view for reflections, refractions etc.
    - Post-processing of camera data before display (hi-lights, image intensifier effect)
- **Drawbacks**
  - There may still be copies in poor implementations
  - Not available on many platforms
- **Fastest, most flexible solution, where available**
  - Preserves bandwidth for processing, doesn't restrict effects



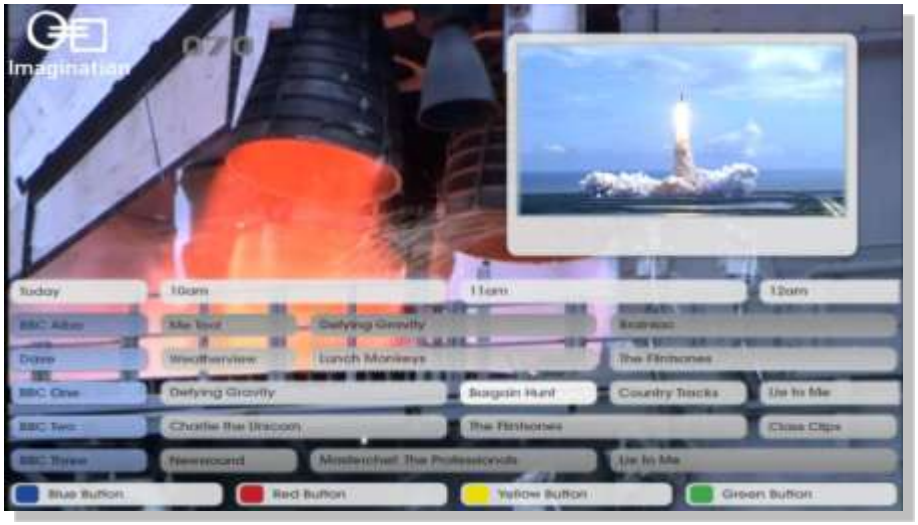
Texture streaming

- **What is texture streaming?**
  - The process of writing images into buffers that can be accessed directly by the graphics hardware
- **Benefits**
  - Fast image access (Zero-copy on UMA devices)
  - Multi-buffered
  - Can be used as a texture
- **Drawbacks**
  - Not available on many devices
  - Lacks a standard API
  - All buffers within a stream must be the same format and resolution
- **Hardware Support is there**
  - All Imagination POWERVR SGX hardware can support this
  - Similar solutions are possible for other hardware



Texture streaming: Examples

- **Set top box demo**
  - Texture streaming allows multiple video streams to be applied to 3D GUI elements
  - HD video in the background
  - All in real-time at high frame-rates



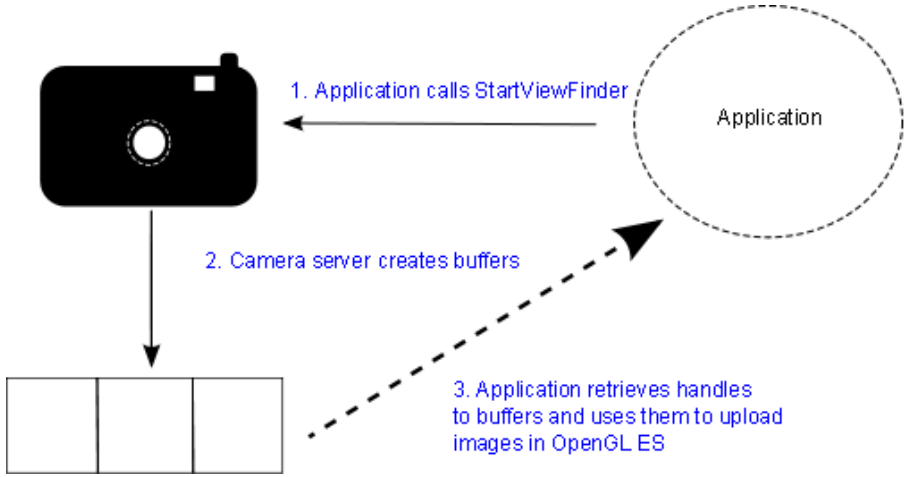
- **Video cube demo**
  - Frames from a video can be used to texture the faces of a cube object
  - Each face has a different post processing effect applied to it
  - All in real-time at high frame-rates

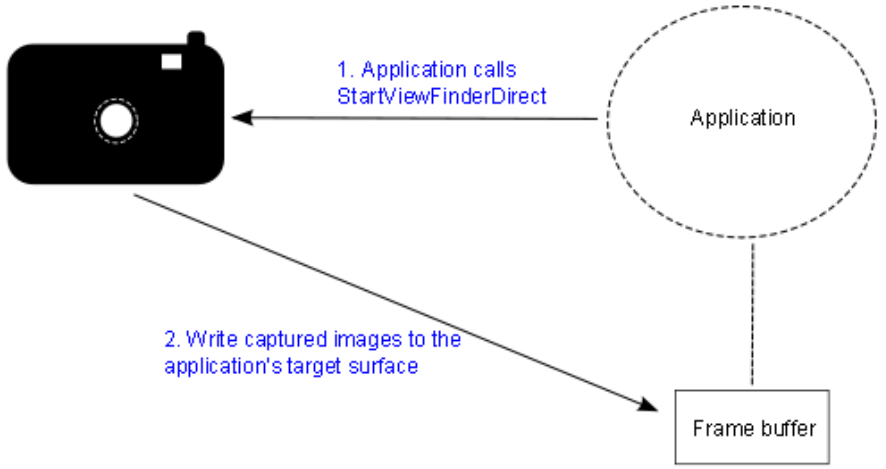
Sony-Ericsson Vivaz

- **Specs**
  - 360x640 pixel screen
  - POWERVR SGX 530
- **Why was this device used?**
  - One of the few currently shipping devices that provides texture streaming functionality

Capturing images on the Vivaz

- **Capturing images**
  - Once the camera server has been started, there are two default Symbian functions for beginning an image capture stream; StartViewFinderL & StartViewFinderDirectL
- **StartViewFinderL**
  - Store captured images in buffers allocated by the camera server
  - **Benefits**
    - Buffers can be mapped into user mode, where the CPU can analyze them
  - **Drawbacks**
    - Slow per-frame upload through graphics APIs
- **StartViewFinderDirectL**
  - Write captured images directly into the frame buffer
  - **Benefits**
    - Fast update of captured images
  - **Drawbacks**
    - Difficult to access the image for CPU analysis
    - Cannot be used as a texture in OpenGL ES

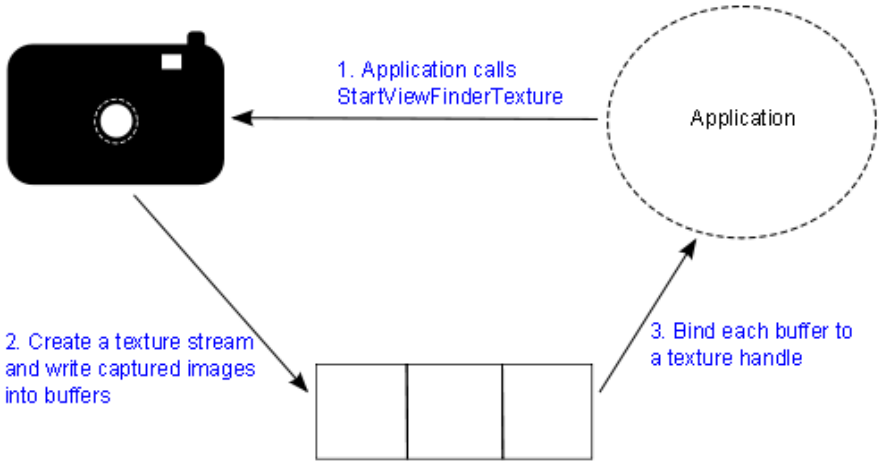




Vivaz Texture Streaming

- **Capturing images**
  - Sony-Ericsson's StartViewFinderTexture & StopViewFinderTexture functions can be accessed through a camera extension
- **StartViewFinderTexture**
  - Write captured images into a texture stream

  Benefits
  - Fast update of captured images
  - Images can be textured onto any 3D object
- **DynamicTexture.h**
  - Provides a user-mode API to the kernel-mode texture stream module
  - Consuming applications can use this to retrieve texture stream information



Texture streams in OpenGL ES 2.0

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- **Imagination's texture stream extensions**
  - void glGetTexStreamDeviceAttributeivIMG(GLint texStreamId, GLenum pname, GLint *params)
  - void glTexBindStreamIMG(GLint texStreamId, GLint bufferId)
  - const GLubyte* glGetTexStreamDeviceNameIMG(GLint texStreamId)

- **Loading textures**

```
glGenTextures(m_i32NoTexStreamBuffers, m_auiTexStreamTexId);

// Bind tex stream textures
glActiveTexture(GL_TEXTURESTREAM);
for(int i = 0 ; i < m_i32NoTexStreamBuffers; ++i)
{
    glBindTexture(GL_TEXTURE_STREAM_IMG, m_auiTexStreamTexId[i]);
    glTexParameterf(GL_TEXTURE_STREAM_IMG, GL_TEXTURE_MIN_FILTER, TEXTURE_STREAM_FILTER);
    glTexParameterf(GL_TEXTURE_STREAM_IMG, GL_TEXTURE_MAG_FILTER, TEXTURE_STREAM_FILTER);

    glTexBindStreamIMG(m_uiTexStreamId,i);
}
```

Texture streams in OpenGL ES 2.0

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- **Use a shader program**
  - Retrieve the ID of the most recently written texture stream buffer
  - Bind the corresponding texture

```
// Use shader program
glUseProgram(m_Tex2DShader.uiId);

// Retrieve the current read buffer number and use it
int i32BufferId = DynamicTexture::CurrentBuffer(bufferDevice);

// Bind the most recently captured image
glActiveTexture(GL_TEXTURESTREAM);
glBindTexture(GL_TEXTURE_STREAM_IMG, m_auiTexStreamTexId[i32BufferId]);

glUniformMatrix4fv(m_Tex2DShader.uiMVPMatrixLoc, 1, GL_FALSE, m_mProjection.ptr());

// Enable the vertex attribute arrays
glEnableVertexAttribArray(VERTEX_ARRAY);
glEnableVertexAttribArray(TEXCOORD_ARRAY);

glVertexAttribPointer(VERTEX_ARRAY, 4, GL_FLOAT, GL_FALSE, 0, &vVertices);
glVertexAttribPointer(TEXCOORD_ARRAY, 2, GL_FLOAT, GL_FALSE, 0, &vTexCoords);

// Draw primitive
glDrawArrays(GL_TRIANGLE_FAN, 0, 4);

// Safely disable the vertex attribute arrays
glDisableVertexAttribArray(VERTEX_ARRAY);
glDisableVertexAttribArray(TEXCOORD_ARRAY);
```

Texture streams in GLSL ES

- **Sample texture stream texture**
  - Enable the GL_IMG_texture_stream2 extension if it exists
  - Indicate that the texture stream sampler (samplerStreamIMG) should be used
  - Use the texture stream sampler to retrieve the texel colour at the specified texture coordinate

```
#ifdef GL_IMG_texture_stream2
#extension GL_IMG_texture_stream2 : enable
#endif

#ifdef STANDARD_TEXTURE
    uniform sampler2D texStream;
#else
    uniform samplerStreamIMG texStream;
#endif

varying highp vec2 TexCoord;

void main()
{
    #ifdef STANDARD_TEXTURE
        gl_FragColor = texture2D(texStream, TexCoord);
    #else
        gl_FragColor = textureStreamIMG(texStream, TexCoord);
    #endif
}
```

Augmented reality demo

- **High frame rate refraction demo**
- **>20,000 polygons in the scene (can support more)**

- **Refraction effect requires texture data to be available to OpenGL ES**
  - Without texture streaming this runs much more slowly

Future of Mobile AR

- **Faster CPUs and GPUs**
  - Better image analysis and graphics
  - Dependency on markers may be eliminated
- **Better cameras and other sensors**
  - More accuracy in interaction
  - Higher video frame rates and resolution
- **More applications**
  - Multiplayer alternative world games
  - Vehicle HUDs

- **GP-GPU image analysis**
  - OpenCL enabled mobile devices are likely to ship within the next year
    - On GPU image analysis

Where to get the POWERVR SDK, Documentation & Support

- **Available through the POWERVR *Insider* Programme**
  - Click on “Developers” on the Imagination website: http://www.imgtec.com
  - Free to join!
- **Benefits of being a POWERVR *Insider***
  - Access to the SDK downloads
  - Documentation – performance guidelines, explanations of POWERVR technologies and utility user guides
  - FAQs
  - Developer forums
  - Direct email contact to POWERVR Developer Technology: devtech@imgtec.com
  - Partner Program
  - Newsletter
  - Cross-promotions through press announcements and print/online media
  - Tradeshow Partnership

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Questions?

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